Monitoring Slump-Earthflow Complex Movement: A Southeastern Ohio Case Study[1]

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ABSTRACT. In the nonglaciated region of southeastern Ohio, slope failures are among the most prominent natural hazards. Slumps are the most common form of slope movement in this area. These rotational earthslides move downslope with minimal deformation along a concave failure plane. Although they are relatively slow moving, slumps can develop with little warning, causing damage to buildings, roads, and other features. Earthflows, also common on this landscape, move downslope on the surface with a high amount of mixing. Characterizing the behavior of slope failures is an essential step in mitigating their effects.

Using an electronic total station, the movement of a slump-earthflow complex located near Athens, OH, was monitored over a 5-month period. The study area is approximately 100 m × 130 m. A grid of 90 points was located on the surface of the slope. Each point was surveyed 10 times. These data are plotted and correlated with precipitation and temperature data collected by the Scalia Laboratory for Atmospheric Analysis at Ohio University.

Movement on the foot of the slump was significantly greater than movement on the toe and crown. Regression analysis indicates that precipitation was a statistically significant factor influencing slope movement, but only accounted for 7% of the movement. Temperature was a statistically significant factor as well, also accounting for only 7% of the movement. Empirical evidence suggests that antecedent precipitation plays an important role in slope movement in this area.

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INTRODUCTION

Slope failures are among the most evident and problematic natural hazards in southeastern Ohio. Three general types of slope failure are prevalent in this region: slumps, earthflows, and rockfalls. Of these, slumps are the largest in scale (Hansen 1995).

A slump is a rotational landslide (or earthslide) that moves downhill with minimal deformation along a concave failure plane (Goudie 1994; Varnes 1958). Slumps have caused extensive damage to buildings, roads, and other features in many areas of the United States. Many slumps exhibit brief periods of rapid movement that are preceded and followed by periods of slower movement. Because the failure plane of a slump lies beneath the surface, in either bedrock or colluvium (weathered material that has moved downslope), determination of the size or even the full extent of a slump can be difficult. This lack of surface expression often results in unpredicted slope movement (Bromhead 1986). Nearly all of the slumps in southeastern Ohio occur in colluvium (Pomeroy 1987).

Another type of slope failure common in this area is an earthflow, which is a downslope surface movement involving a substantial amount of mixing of the surface material (Goudie 1994; Hansen 1995). Earthflows move at varying rates depending on factors such as slope angle and flow composition. Finally, rockfalls are very rapid movements of fractured pieces of bedrock from near vertical slopes (Goudie 1994; Hansen 1995). In Ohio, most rockfalls involve large, fractured masses of sandstone and limestone that have been subjected to the weathering action of freeze-thaw cycles (Hansen 1995).

In 1968, the average annual cost of slope failure damage to Ohio highways was estimated at approximately $1 million (Fisher and others 1968). However, this cost may be substantially higher for counties in non-glaciated regions of Ohio that have extensive roadways. For example, from 1973 through 1978, Hamilton County incurred an average annual damage cost of over $5,000,000 from landslides (Fleming and Taylor 1980). Besides this direct damage, landslides also contribute to decreased agricultural productivity, reduced real estate values, flooding, and compromised water quality (Fleming and Taylor 1980). Despite such losses, very few natural hazard management practices have had a substantial influence on landslide impacts (Keefer and others 1987).

Many previous studies have described landslide characteristics and the factors affecting slope instability in Ohio (Carlson 1977; Fanaff 1964; Kufs 1978; Pennell 1990; Sowers 1975). However, very few studies have carefully documented the movement of an unstable slope through time (Schwab 1981). Until recently, measurements of slope movement were limited by the accuracy of the instrument used for monitoring. Today, using a Topcon GTS-302 electronic total station (ETS), it is possible to observe the movement of an unstable slope with a high degree of accuracy. This instrument measures to within 0.2 cm, which not only allows for precise monitoring, but can also be useful in determining the slope of a subsurface failure plane (Saffer and Dethier 1996). Correlating slope movement with atmospheric data from a meteorological observatory can help isolate the weather conditions that most influence slope movement.

The work reported here is a case study that involves measuring slope movement rates and examining how

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those rates are influenced by local precipitation and temperature regimes. Specifically, this study investigates the rainfall patterns and temperature changes that contribute to spatially variable rates of slope movement, measured by an ETS, on the Monticello Village Apartment slump-earthflow complex near Athens, OH. Through a better understanding of the mechanisms that promote slope failure in southeastern Ohio, the accuracy of landslide prediction can be improved. Accordingly, improved natural hazard management practices may become possible if appropriate zoning regulations, based on the potential for slope failure, can be implemented. Finally, this work provides a contribution to the knowledge of both past and present erosional processes. Slumps are commonly recognized features in the paleoenvironmental record and are important sediment transport mechanisms (Prothero and Schwab 1996; Shearer 1993). Understanding how modern slumps develop and move can provide insight into slump events in the past.

MATERIALS AND METHODS

Location and Site History

The study site is a slump-earthflow complex located in the nonglaciated portion of southeastern Ohio just south of the Hocking River near the southern boundary of the City of Athens (Figs. 1,2). This slump-earthflow complex contains two major slumps, referred to as the northeast slump and southwest slump, and one major earthflow (Fig. 3). A few minor earthflows are found on the foot and crown. The study site measures 100 m wide at the toe and 113 m wide at the crown (Fig. 4). The length of the slope, from the toe through the foot to crown, is approximately 131 m as measured overland by tape. The toe is located 10 m southeast of State Route 32. The Hocking River channel lies approximately 150 m northwest of State Route 32 (Fig. 2). The State of Ohio owns the entire study site.

FIGURE 1. Location of Athens within the state of Ohio.

The recent mass-wasting history of the study site is well documented because of the dramatic impact of the slump-earthflow complex on buildings and infrastructure, and the impact of those structures on the slump-earthflow complex. Despite nearby physical evidence of slope instability, including lobes of previous landslides, hummocky topography, tilted fence posts, dead trees, and previous road damage from slope movement (Sowers 1975), the Monticello Village Apartments, a 14-building apartment complex, were constructed on the top of the slope in 1968. Several of these buildings were located directly on what would become the crown of the slump-earthflow complex (Sowers 1975). In October 1972, during an unusually wet autumn (Table 1), one of the buildings was removed to reduce the load on the crown and thereby decrease the chance of slope failure. Despite this action, on 4 November 1972, the slope failed, causing the destruction of a 150 m section of Hastings Road in the present location of State Route 32 (Amey 1972). Three days later, on the evening of 7 November, four buildings were evacuated after heavy rainfall resulted in additional rapid movement of the slope (Amey 1972). By July 1974, a total of 9 buildings had been removed from the site due to the continued threat of slope movement (Sowers 1975).

Physical Setting

Clinometer measurements show that the average slope of the study site is 23°. Angles within the study site vary from 0° on top of the toe and major scarps to 90° on several of the exposed bedrock ledges. The bedrock underlying the study site consists of Paleozoic mudstones, shales, sandstones, and limestones. These sedimentary strata are part of the Conemaugh Group, deposited during the Pennsylvanian Period (Sturgeon 1958). The Skelley sandstone from this group is exposed just above the foot of the slump (Sturgeon 1958). Laminated red shales within this section are very prone to sliding (Brennan 1998; Hansen 1995; Picking 1965). The strata dip approximately 5.7 m/km to the east-southeast (Sturgeon 1958).

The surface of the study site prior to slope failure was comprised of soil and regolith (Sturgeon 1958). In 1968, construction work on the apartment complex included cutting a terrace into the slope. This terrace was to be used as the building pad. The material removed to form the terrace was used to fill and smooth the slope below the building site (Sowers 1975). A subsurface investigation report prepared by H. C. Nutting Company in 1971 revealed that fill that was placed on the slope had high porosity and low permeability (Sowers 1975). This is characteristic of the illitic clays that are common in the soils of southeastern Ohio (Hooper 1969; Picking 1965; Webb and Collins 1967).

Currently, the slope consists of a very poorly sorted colluvium comprised of fill, residuum, and substantial amounts of concrete, asphalt, metal, wood, ceramic, and plastic particles introduced from the destruction of the apartment buildings during the slope failure. Based on field observations, the soil in the study site shows very

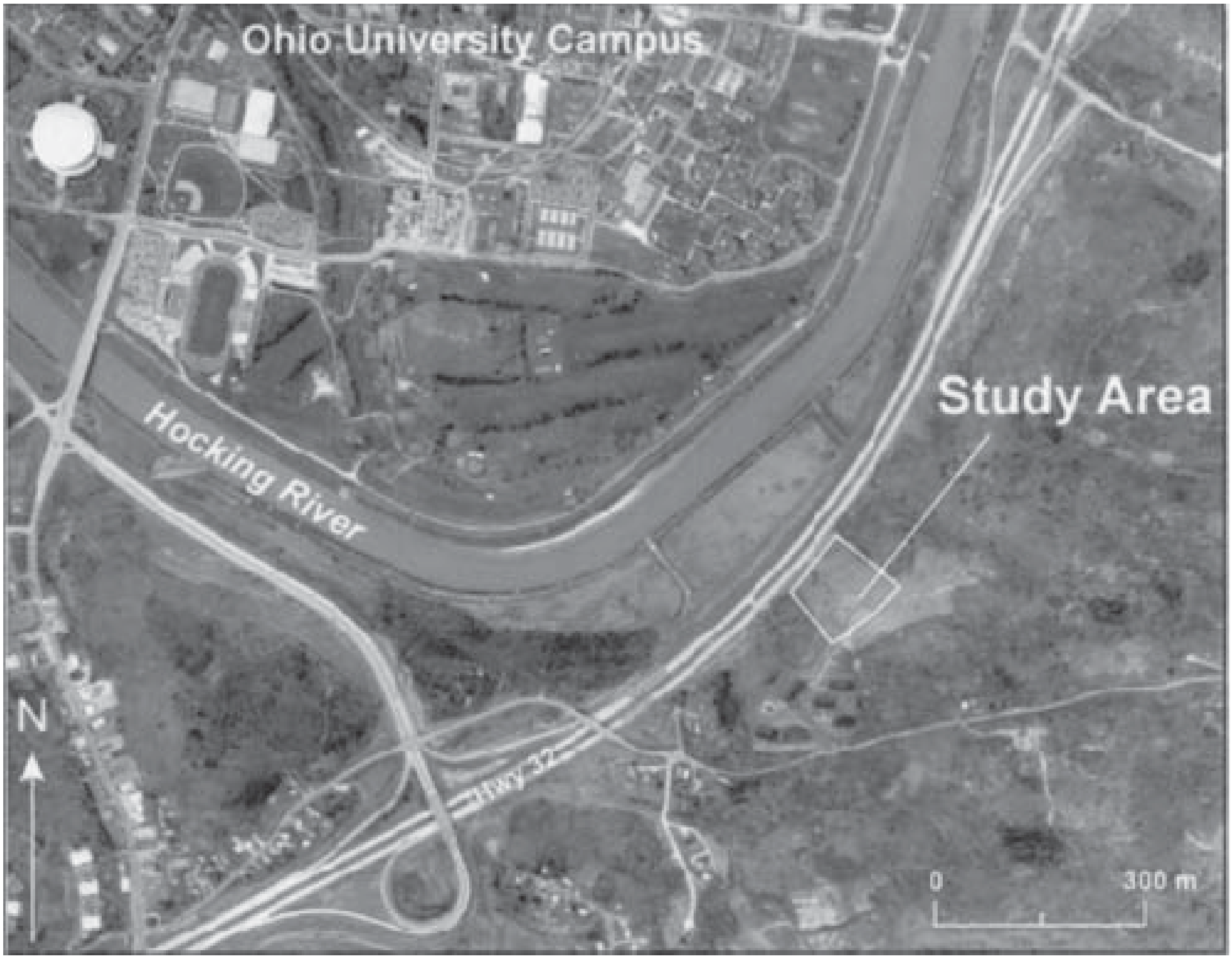

FIGURE 2. Aerial view of the slump-earthflow study and its relative location with respect to local landmarks.

poor horizon development, likely the result of frequent disruption during slope movement. Particle sizes of natural materials range from clay to large boulders. Particle sizes of artificial materials range from sand-size pieces of ceramic to large boulder-size pieces of foundation (concrete) and interior walls.

Southeastern Ohio has a humid continental climate. Winters are usually cold while summers are hot and humid. Air masses come from continental sources to the north and west, and maritime sources to the south and east. Precipitation is evenly distributed throughout the year except for a slightly wetter period during spring (March – May). Records from the Scalia Laboratory for Atmospheric Analysis at Ohio University in Athens show that from 1965 through 1995, the City of Athens received an average of 99 cm of precipitation per year. The average annual temperature during this time was 17° C.

The vegetation cover in the study site varies considerably. The area of the earthflow is completely devegetated. Vegetation on the crown (Fig. 4) is composed entirely of short grasses and small forbs. The middle and upper portions of the foot are not as densely covered as the crown and have a mix of grasses, forbs, and shrubs, along with several pine seedlings. The lower foot and the toe are the most densely vegetated with several broadleaf, deciduous tree species, including eastern redbud (*Cercis canadensis* L.) and flowering dogwood (*Cornus florida* L.). Based on diameter at breast height (dbh), most of the trees at the study site are estimated to be less than 30 years of age. However, several white oak (*Quercus alba*) trees located near the upper foot are substantially older. Many of the smaller trees located on the foot have rotated back towards the surface of the slope at angles as much as 60°, a reliable indication of recent slope movement.

Other slopes in the vicinity of the study site are also actively slumping. Vegetated areas composed primarily of mixed deciduous forest separate the study site from these other active slopes. Even the bordering areas of denser vegetation display some evidence of slope movement, such as tilted trees and hummocky topography. However, the rate of slope movement appears to be much slower on the adjacent forested slopes than at the study site, possibly a result of the stabilizing effects of vegetation. Although these adjacent slopes may be potentially unstable, they likely provide some lateral support for the sides of the slump-earthflow complex of the study site at this time.

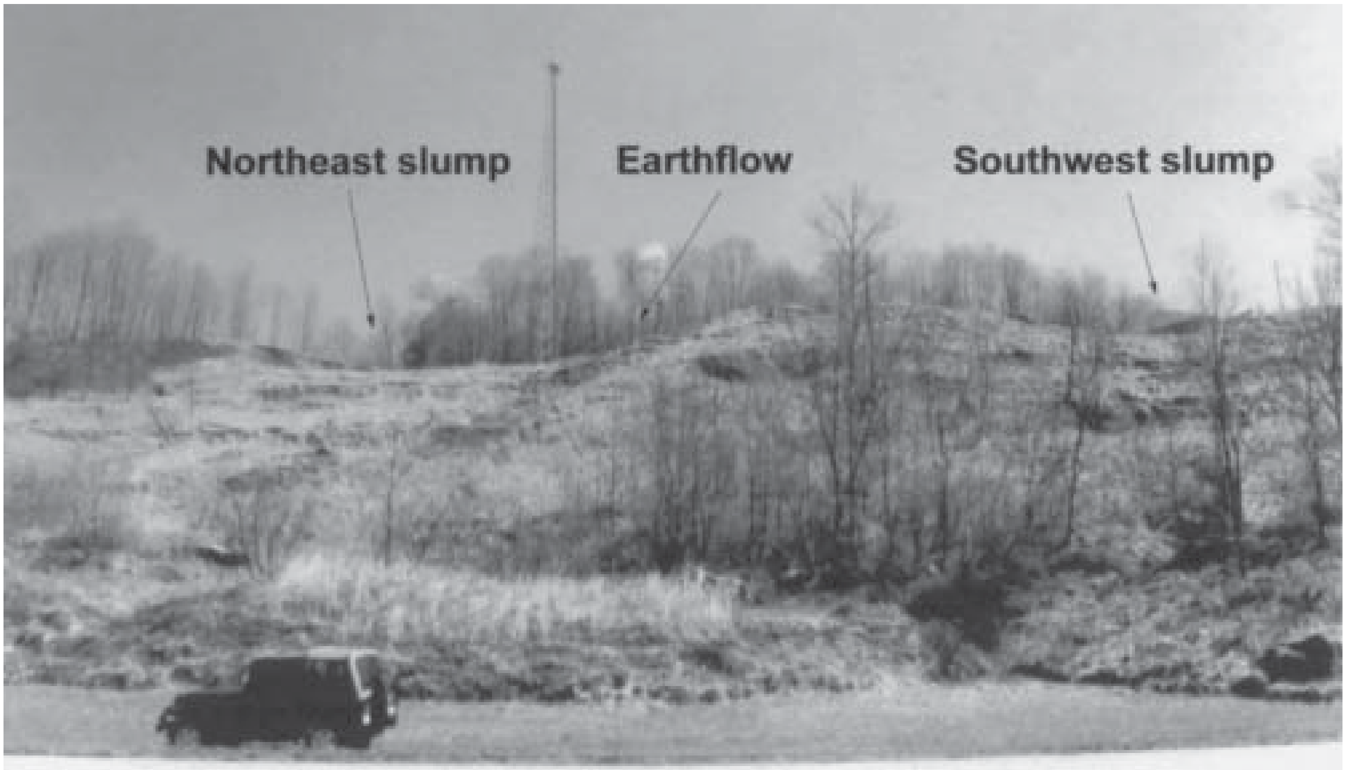

FIGURE 3. Photograph of study site. State Route 32 is present in the foreground. The earthflow component is the darker, completely devegetated strip just to the left of center.

Data Collection

Data collection began in late September 1997, after permission was obtained from the State of Ohio to access the property on which the study site is located. Preliminary observations, including slope dimensions, slope angle, soil composition and particle size, and vegetation composition, were collected during late September and early October. Photographs were taken during the entire study period (20 November 1997 to 28 April 1998) to document changes in the surface expression of the study site. Ninety-two pin flags were placed in a 100 m × 100 m grid on the surface of the slump-earthflow complex (Fig. 4). Every effort was made to locate each pin 10 m away from adjacent pins, but surface features often required adjustments to the final locations of the pins. Each pin was numbered for identification and inserted vertically into the surface to a depth of approximately 15 cm. Pins 1 to 32 were located on the toe. Pin 25 was eventually excluded from the study due to obstruction from the instrument by the surrounding vegetation. Pins 33 to 70 were positioned on the foot, and pins 71 to 92 were placed between the upper foot and the crown. Two points located on a guardrail on State Route 32 were established as control point 1 and control point 2. These particular points were chosen because their location is fixed and not influenced by slope movement.

On 20 November 1997, the initial position of the pins and control points were surveyed using an ETS shooting to a prism target. For each point during each survey, the prism rod was kept at a constant height and the prism was consistently placed immediately downslope of each pin. Vertical distance, horizontal distance, and overland distance from the instrument station were recorded for each pin. Beginning in late November 1997, the pins were surveyed 10 times in the same manner over a 23-week period using the ETS (Table 2). Due to logistical constraints, this was the maximum length of time over which the study could be conducted. The amount of time between surveys varied due to logistical constraints. During the later portion of the study period, several pins near the main scarps in the crown area were lost due to surface movement. This reduced the number of pins to 84 and eventually to 82. Data from Survey B could not be used because of measurement error incurred at the time of the survey.

Hourly precipitation and temperature data were obtained from the Scalia Laboratory for the period of 1 November 1997 to 28 April 1998. The data were used to calculate precipitation and mean temperature for the intervals between surveys as well as for the entire study period. That facility, which houses a meteorological station, is located approximately 0.5 km from the study site. Because of the close proximity of the study site and the Scalia Laboratory, it is assumed that the amount of precipitation received at these locations is approximately equal.

Data Analysis

Following the completion of the final field measurements on 28 April 1998, the data from each survey were recorded in a spreadsheet for analysis. Adding or subtracting the difference between the instrument heights of each survey and the instrument height of Survey A from

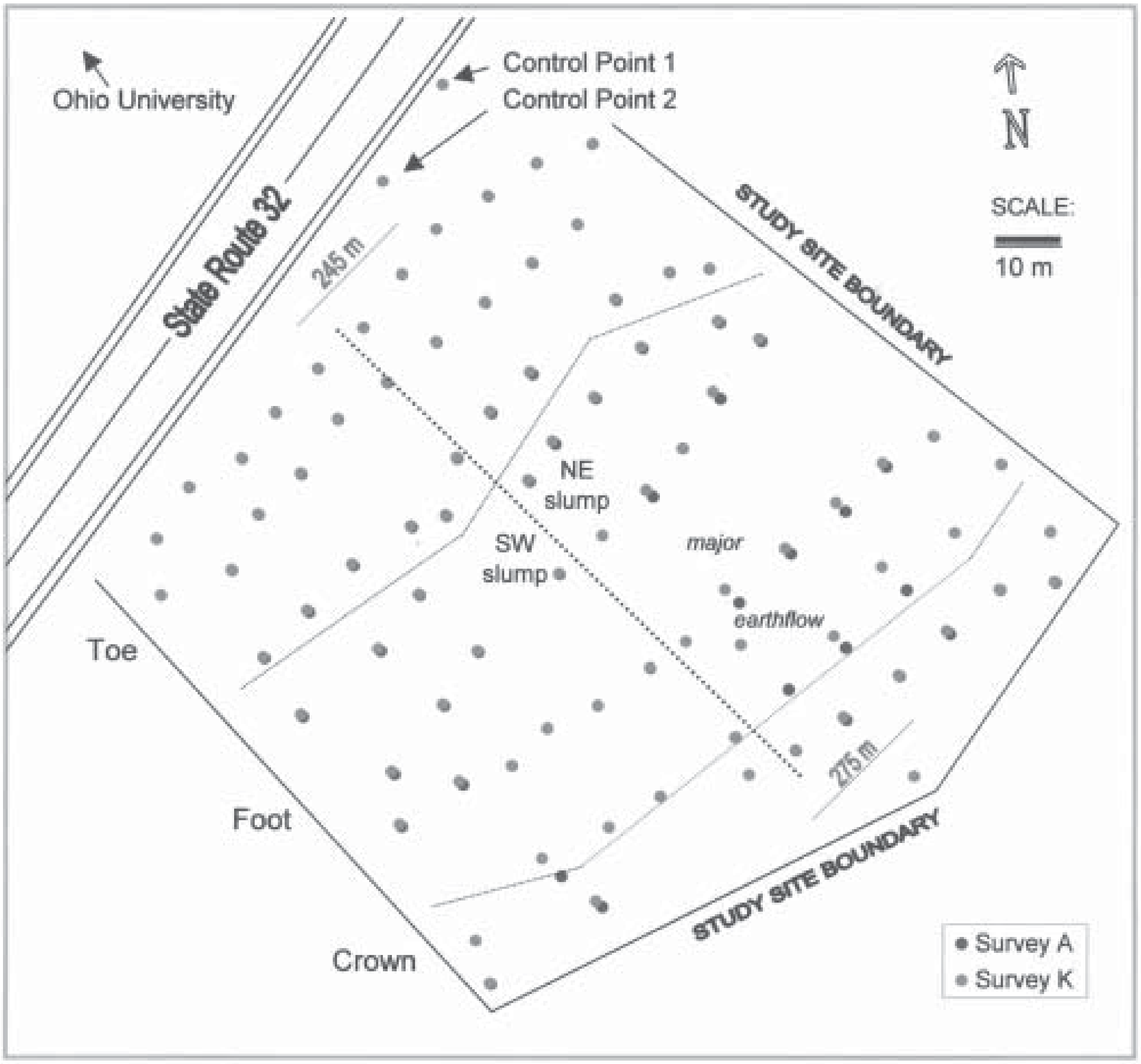

FIGURE 4. Planimetric map showing pin locations at the start of the study (Survey A) and at the end of the study (Survey K).

TABLE 1

Precipitation at the Ohio University Department of Geography Scalia Laboratory during autumn of 1972.

Period	1972 (cm)	1965 - 1995 Average (cm)
1-31 August	11.71	7.80
1-30 September	12.80	7.34
1-31 October	8.89	5.26
1,2 November	3.48	
7 November	3.68	

each pin elevation provided corrected pin elevations. Next, the surveyed planimetric positions (x and y locations) of all pins were corrected by 1) translating each survey's grid to a common origin (control point 2) and 2) rectifying the grid to a common y axis line between control point one and control point 2. The change in planimetric overland distance from the instrument location (control point 2) to each pin was calculated for each survey and for the entire study period.

Using multiple regression, pin movements were statistically correlated with the precipitation and temperature data from the Scalia Laboratory. Multiple regression was used to help predict the nature of the relationships between variables that may have otherwise been obscured in first-order (linear) regression models. Specifically, the values of 738 movement observations were correlated with precipitation and mean temperature between each survey to detect the extent to which precipitation and

TABLE 2

Description of surveys.

Survey	Date	No. of Points Surveyed	Days Elapsed Since Previous Survey
A	11-20-97	91	–
C	01-25-98	91	60
D	02-01-98	91	7
E	02-08-98	91	7
F	02-15-98	91	7
G	02-22-98	91	7
H	03-01-98	91	7
I	03-31-98	84	30
J	04-15-98	82	15
K	04-28-98	82	13

temperature influenced slope movement. Because many of the movement values are near zero, a coded qualitative variable was calculated based on pins that moved at least 30 cm (assigned a value of 1) and pins that did not move at least 30 cm (assigned a value of 0). Pins that were lost in the later portion of the study period were not included in the analysis.

The influence of temperature range was not analyzed in this study. Although atmospheric temperatures occasionally fell below the freezing point, it is unlikely that the moisture below the surface froze for even a short period of time. *T*-tests were used to determine if the differences in the amounts of movement between the toe, foot, and crown were statistically significant.

RESULTS

Results of Data Analysis

Slope movement is summarized in Table 3. Thirty points moved at least 30 cm and 52 points moved less than 30 cm. The sum of the movement of all points over the entire study period is 523.4 cm; this value is presented here only to emphasize the active nature of the slump-earthflow complex. Over the 23-week study period, the average amount of movement of a pin was 64 cm. The greatest amount of movement was observed at the last survey; the average pin movement between Survey J and Survey K was 13.8 cm. The most mobile point in the study area moved over 11 m and was located on the major earthflow. Other points on the major earthflow also showed substantial movement over the duration of the study period. Pins located on two minor earthflows did not show substantial movement. Figure 4 displays the location of all pins at Survey A and Survey K.

The amount of precipitation and the mean temperature between each survey appear in Table 4. During the study period, 53.8 cm of precipitation was recorded. The mean temperature was 5.3° C. Results of the regression analysis must be placed in context

Table 3

Summary of slope movement during the study period.

Period	Total Pin Movement [1] (cm)	Average Pin Movement (cm)	Average Daily Pin Movement (cm)
Survey A – Survey C	408	4.5	0.08
Survey C – Survey D	325	3.6	0.51
Survey D – Survey E	308	3.1	0.44
Survey E – Survey F	592	6.5	0.93
Survey F – Survey G	638	7.0	1.00
Survey G – Survey H	585	6.4	0.91
Survey H – Survey I	1020	12.2	0.41
Survey I – Survey J	508	6.2	0.41
Survey J – Survey K	1131	13.8	1.06
Total Study Interval	5234	64.0	5.75

[1]Sum of all points.

TABLE 4

Precipitation and temperature between each survey.

Date	Precipitation (cm)	Mean Temperature (° C)
1 Nov 1997 – Survey A	4.9	3.3
Survey A – Survey C	14.4	-0.4
Survey C – Survey D	0.3	2.9
Survey D – Survey E	5.4	2.0
Survey E – Survey F	0.5	4.7
Survey F – Survey G	5.1	5.8
Survey G – Survey H	1.4	7.4
Survey H – Survey I	6.8	2.8
Survey I – Survey J	5.5	49.2
Survey J – Survey K	9.6	15.6
Total study interval	53.9	5.3

of the climatic regime that was present during the study period for the most accurate interpretation. El Niño, the periodic disruption of the strong hydrologic cycle in the Pacific Ocean, had pronounced meteorological effects in 1997-1998. During an El Niño cycle, the disruption of cold water upwelling off the western coast of South America and the establishment of a large, warm plume of surface water in the mid-Pacific alter the location of the subtropical jet stream and the distribution of Pacific storms. This results in changes in weather patterns for many locations throughout the world. In southeastern Ohio, El Niño years typically have above normal precipitation from November through December and below normal precipitation from January through May (NOAA 1998). During the study period, above normal precipitation was received in 4 out of the 6 months, most notably in February. Temperatures were several degrees above normal from December through March. Above normal precipitation and temperature may result in greater or lesser amounts of slope movement than normally occurs in non-El Niño years. The deviations of the 1997-1998 precipitation and temperature values from the average values in this area are provided in Table 5.

Slope movement appears to be only slightly influenced by temperature and precipitation at the study site. An r^2 value of 0.070 and a significant F value of 27.751 indicate that the precipitation that was received in the interval since the previous survey accounts for approximately 7% of the variability of total slope movement. The mean temperature that was recorded in the interval between surveys is also a statistically significant factor in determining the amount of slope movement in the study site, accounting for approximately 7.4% of the variability of total slope movement.

Substantial differences were observed in pin movement between each of the zones in the study area (toe, foot, and crown). On average, points located on the toe moved 15.4 cm, the shortest distance of the three zones. In contrast, the average movement of points located on the foot was 110.5 cm. Points within the crown exhibited an average of 19.1 cm of movement. Based on a two-tailed t-test with an alpha level of 0.05, movement within the foot was significantly greater than the average movement of points within both the toe and crown. These statistically significant differences are likely the result of the steeper slope in this zone, which increases the shear stress on the surface material.

In addition to varying amounts of movement between the 3 zones of the slump-earthflow complex, differences in the amount of movement between the 36 pins on the northeast slump and the 33 pins on the southwest slump were observed. Pins on the northeast slump, not including pins located on the major earthflow, moved an average of 15 cm during the study period, whereas points on the southwest slump moved an average of 11 cm. This difference was not found to be significant based on a two-tailed t-test with an alpha level of 0.05. The 11 pins between the northeast and southwest slumps, with the exception of points on the major earthflow, showed very little movement.

TABLE 5

Mean precipitation and temperature at the Scalia Laboratory.

Month	Precipitation (cm)	Temperature (° C)
1965 – 1995		
November	7.0	6.0
December	7.3	0.4
January	7.8	-0.8
February	7.0	1.1
March	10.2	6.8
April	9.1	12.5
1997 – 1998		
November	7.8	5.7
December	6.7	2.8
January	9.7	4.4
February	12.4	4.9
March	8.0	13.5
April	9.1	12.5

DISCUSSION

The Role of Water

Although regression analysis indicates that precipitation accounts for only a small percentage of the variability in slope movement, a closer analysis reveals that rainfall may be an important factor influencing movement of the slope. The complexity of the relationship between antecedent precipitation, evaporation, and groundwater responses likely accounts for the low coefficient of determination of the slope movement and precipitation regression analysis. During the period between Survey D and Survey E, 5.4 cm of rain fell in one week. However, only 308 cm of total movement was recorded during Survey E. Precipitation data from Scalia Laboratory show that nearly all of this moisture was received on 4-5 February. Over the following week, only 0.5 cm of rain fell, but twice as much movement was recorded. This delayed movement can be explained by pre-storm moisture conditions of the material on the slope.

Early in a wet season, groundwater responses are strongly influenced by the amount of antecedent water in the subsurface (Iverson and Major 1987). Deep groundwater tends to respond more slowly to precipitation events than does shallow groundwater (Iverson and Major 1987). Once enough water has accumulated in the colluvium, slope movement is dependent on the amount of precipitation received from the next storm (Pomeroy 1984). For the last 3 survey periods, a strong correlation exists between precipitation and slope movement. With ample water in the subsurface from 6.5 cm of rain during the previous 2 weeks, and low temperatures limiting the amount of evaporation, negative pore pressures had likely been eliminated. Also, groundwater response was likely very rapid due to the saturated conditions. The amount and timing of slope movement provide empirical evidence that antecedent precipitation may be the determinant factor controlling the amount of future precipitation needed for slope movement.

In terms of evaporation, higher temperatures should result in a *decrease* in slope movement as water is removed from the soil. Instead, this analysis indicates that an increase in temperature produces a very slight *increase* in slope movement. It is unlikely that the moderate temperatures experienced during the study period produced substantial differences in rates of evaporation between the surveys. Instead, this correlation is likely the result of differential expansion of the soil with increases in soil temperature, which correspond to increases in atmospheric temperature (Schwab 1981). Also, higher soil temperatures result in increased biologic activity, which alters the physical structure of the soil, possibly promoting slope movement.

Since the landslide activity of the early 1970s, the Monticello slope has remained active. Aerial photographs from 1974, 1985, and 1990 show distinct changes in the vegetation cover and physical surface features. Over the duration of the study, the major scarp of the northeast crown retreated 150 cm. Subsequent field observations reveal many changes even over short periods of time. New lateral scarps, the movement of large amounts of surficial material, and changes in the geometry of existing scarps all indicate substantial downslope movement. Although changes in the surface features of the slump-earthflow complex were evident throughout the study period (Fig. 5), the development of new lateral scarps and minor scarps were observed frequently during April of 1998. During the last 2 weeks of April, depressions that were normally filled with water dried completely, while new depressions and previously well-drained depressions had water depths up to 46 cm. This indicates changes in surface and/or subsurface drainage patterns. Water-flow paths are dynamic in both space and time; changes in flow patterns often result from movement of material on the slope (Harp and others 1990). Saturation of the slump-earthflow complex between the highway and the toe was also observed during the entire month of April. Even 1 week after a rainfall event, the surface remained completely saturated. It is possible that these changes in the surface features and drainage regime are at least partially the result of alterations made to the crown by the construction of a telecommunications mast during the study period.

On 3 December 1997, a permit was issued for the construction of a telecommunications mast 23 m from the edge of the northeast crown, approximately in the former

FIGURE 5. Photograph of earthflow movement that occurred during the study period (clipboard in foreground for scale).

location of one of the destroyed apartment buildings. Construction of the mast began in early February 1998. A concrete pad measuring 13.7 m × 10.7 m × 0.9 m was constructed first to serve as the support platform. A large electrical transformer was installed on the platform. The mast, which extends to a height of 59.4 m above the surface of the crown, was then erected, followed by a wooden fence surrounding the base of the mast. Initially, 2 drainage outlets, which discharge runoff onto the surface of the crown, protruded from the platform. In late March 1998, PVC piping was attached to these outlets and the outlets were covered with gravel. The piping submerges into the surface of the crown and reemerges on the surface of the major scarp of the slump-earthflow complex before submerging again. This piping apparently conducts water directly from the platform to the slump-earthflow complex. As a result, pore water pressure on the slump-earthflow complex has likely increased since construction of the mast.

Slope Hazard Management and Future Research

In southeastern Ohio, where a high potential for slope failure exists in many areas, natural hazard management can be improved by monitoring the pre-storm conditions of slope material. This can be accomplished by installing monitoring equipment, such as piezometers, on slopes that are determined to be at risk of failure. However, this would require a substantial commitment of funding, personnel, and time. A simpler and less expensive method would be to issue warnings when ample amounts of precipitation have been received prior to additional incoming storms. The issuing of such warnings should involve the integration of meteorological and geomorphological staff.

Future study should incorporate several additional aspects of analysis. Although regression analysis indicates that temperature contributed only slightly to slope movement in this area during the study period, monitoring of slope movement during warmer months could help determine the importance of increased temperatures and levels of evaporation. A water budget analysis could indicate how temperature and evaporation affect slope movement. This type of analysis could also more accurately explain the role of antecedent precipitation by assessing changes in groundwater storage and surface runoff. The influence of the telecommunications mast, in terms of added weight on the crown and alteration of the drainage regime, has not been fully assessed. It is possible that the telecommunications mast is resulting in increased slope movement.

It is the continuing responsibility of earth scientists to assess hazardous situations as best as possible and to help assure the transmission of those assessments to the public. Often, assessment becomes very complex due to multi-dimensional human interactions with the physical environment. In areas where assessment is difficult or the potential for loss is high, many observers argue that humans should not modify the landscape (McPhee 1989). Although history has taught many lessons about such modifications, occasionally the lessons need to be reinforced. One month after the 25th anniversary of the Monticello Apartment Village landslide, a building permit was issued for the exact same location. The economic, social, and political structures that allowed this permit to be issued should be studied in detail.

Although this study covered a 23-week period, additional slope monitoring could be beneficial. It is recommended that further study employ more permanent markers than pin flags and a fixed instrument station or control point between the Hocking River and the Ohio University bike path. Alternatively, global positioning system transmitters could be deployed at the original pin locations and a receiver could be installed on the Ohio University campus for long-term monitoring. Correlated with atmospheric data from the Scalia Laboratory, long-term measurements may further isolate the weather patterns and slope alterations that most influence slope movement.

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